

climatic conditions than those which exist today. Archaeologists^{2,3} have also emphasized the occurrence of intermittent floods in the Indus valley during the Harappan period. These conclusions, which are based on archaeological evidence, are also supported by the following meteorological considerations.

The patterns of 1,000–500 mbar thicknesses recently published by Lamb, Lewis and Woodroffe⁴ clearly indicate that in 2000 and 500 BC, there was a mean trough in the upper westerlies with its axis along 70° E. and extending from high latitudes to 45° N. in the month of July. These thickness charts do not indicate the existence of such a mean trough anywhere between 0° E. and 160° E. in modern times.

I have made a detailed study of the daily northern hemisphere charts for 1962–66, with good coverage of data to the north of the Indo-Pakistan sub-continent, and have found that quasi-stationary troughs in the westerlies at the 500, 300 and 200 mbar levels occasionally extend into north-west Pakistan and induce monsoon activity ahead of such troughs⁵. They are deep enough to alter the configuration⁶ of the sub-tropical high to their east and are thus indirectly responsible for causing any monsoon depressions moving in a west-north-westerly direction towards longitude 78° E., to curve to the north or north-east towards the Punjab (Pakistan), Punjab (India) and Kashmir (Fig. 1). Before the depression curves to the north, the area of heavy rainfall lies in the left front quadrant⁷ of the depression. After the depression has curved to the north, however, this area of heavy rainfall shifts to the northern sector of the depression, with the active monsoon area chiefly determined by the area of high level divergence ahead of the trough in the upper westerlies^{8,9}. In the later stages of its north-eastward movement, the monsoon depression causes floods in the upper reaches of the Himalayan rivers to the west of 78° E. An example of this can be seen in the monsoon depression of September 2–9, 1966. Such depressions curving to the north or north-east were, however, only very occasional during 1891–1960 (ref. 9).

It follows that during the south-west monsoon seasons around 2000–500 BC deep troughs in the upper westerlies must have extended into west Pakistan far more frequently than they do now, inducing monsoon activity and also causing any monsoon depressions from the Bay of Bengal moving towards longitude 78° E., to curve to the north or north-east. These developments would have caused frequent active monsoon conditions over the entire Indus Valley, which is basically a fertile region¹⁰. Thick vegetation and marsh jungles inhabited by fauna as described by archaeologists¹, and intermittent floods in the Indus and its tributaries, would therefore have characterized the period of the Harappan civilization.

These conclusions are further supported by the recent discovery of considerable reserves of ground water¹¹ in the arid region of extreme west Rajasthan close to the Indus Valley. Carbon-14 tests carried out¹² by staff of the Tata Institute of Fundamental Research in Bombay, at a place called Palana, 14 miles south of Bikaner (28° 00' N., 73° 18' E.) indicate that the ground water there is about 5,000 yr old, this being the upper limit of the true age of the water.

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¹ Wheeler, M., *The Indus Civilisation*, Cambridge History of India, 5 (Camb. Univ. Press, 1956).

² Wheeler, M., *Civilisation of the Indus Valley and Beyond*, 75 (Thames and Hudson, 1966).

³ Kosambi, D. D., *Culture and Civilisation of Ancient India in Historical Outline*, 62 (Routledge and Kegan Paul, London, 1966).

⁴ Lamb, H. H., Lewis, R. P. W., and Woodroffe, A., *World Climate from 8000 to 0 B.C.*, Proc. Intern. Symp., 199 (Royal Meteorol. Soc., 1966).

⁵ Ramaswamy, C., *Indian J. Meteorol. Geophys.*, **18**, 2, 177 (1965).

⁶ Ananthakrishnan, R., and Bhatia, K. L., *Monsoons of the World*, 157 (India Meteorol. Dept., 1958).

⁷ Pisharoty, P. R., and Asnani, G. C., *Indian J. Meteorol. Geophys.*, **8**, 15 (1957).

⁸ Ramaswamy, C., *Tellus*, **8**, 26 (1956).

⁹ *Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea* (India Meteorol. Dept., 1964).

¹⁰ Stamp, D. L., *The World*, 119 (Orient Longmans, 1959).

¹¹ Rao, K. L., *Indian Geohydrology*, **1**, 2 (Indian Assoc. Geohydro., 1965).

¹² *Report to the Indian National Committee for International Hydrological Decade* (Tata Institute of Fundamental Research, Bombay, 1966).

Ultra-low Levels of Terrestrial Ionization

NEHER has suggested¹ that the approximate lower limit of the exposure rate resulting from soil radioactivity be taken as 1.4 μ r./h, an unpublished value measured by Millikan in Manitoba. Subsequent surveys in Europe and the United States^{2,3} reported minimum values for the intensity of terrestrial ionization which averaged approximately 4.5 μ r./h. Millikan's value was also less than that found in the exhaustive study by Hultqvist⁴, in which the lowest indoor gamma level, as measured in wooden houses, was about 5.5 μ r./h.

In 1962, however, during another survey organized by the Health and Safety Laboratory of the US Atomic Energy Commission, Beck *et al.*⁵ measured 1.6 μ r./h at Copperopolis, California. At a nearby asbestos mine (Pacific Asbestos, Inc.) a value of 0.5 μ r./h was measured. The credit for pointing out the diminished radioactivity in this region must go to Wollenberg and Smith⁶, who during a search for low-activity materials for counting room enclosures "discovered" not only the Copperopolis site but also an underground facility, the abandoned Red Mountain magnesite mine in the Diablo Mountains in Santa Clara County, California.

In the late summer of 1965 we visited the Red Mountain mine with a thin-walled (0.5 g/cm² 'Plexiglas') air-filled ionization chamber. This type of chamber has been described elsewhere⁷. After subtracting the cosmic ray contribution, estimated at 0.01 μ r./h, the magnitude of the ionization measured in this mine was 0.05 μ r./h, with approximately a 100 per cent error (Table 1). Even 0.1 μ r./h is a remarkably low value for terrestrial ionization. In New York City, for example, the average background is at least two orders of magnitude larger. Oddly enough, radon was detected during these measurements, and there is the possibility that it originated outside the mine⁸, in which case the ionization levels associated with this mine may be even lower.

We also conducted ionization measurements at the Pacific Asbestos open-strip mine at Copperopolis and obtained a value of 3.94 μ r./h. This is the same (to within the ± 0.09 μ r./h error) as the value reported by Shamos and Liboff⁷ for the cosmic ray ionization at this pressure (734.7 torr), again implying quite small terrestrial levels.

Table 1. SELECTED IONIZATION INTENSITIES OVER SOIL, NOT INCLUDING COSMIC RADIATION

Location	Exposure rate (μ r./h)	Reference
Manitoba	≥ 1.4	1
Red Mountain mine, Santa Clara County, California	≥ 0.05	
Pacific Asbestos mine, Copperopolis, California	≤ 0.09	
Ruberoid mine, Eden Mills, Vermont	1.04 ± 0.21	
Jeffrey mine, Asbestos, Quebec	≤ 0.09	
Jeffrey mine (after heavy rain)	0.57 ± 0.14	
King Beaver mine, Thetford, Quebec	0.10 ± 0.17	
Salt mine, Houston	~ 0.2	*
Denver, Colorado	12.4 ± 1.7	5
Pelham, New York	6.8 ± 0.4	6
Courtright Reservoir, California	20.7 ± 1.4	8
Guarapari, Brazil (monazite sand beaches)	$\leq 2,000$	9

All sites are above ground except for the Red Mountain mine, which is 400 ft. below the surface.

* Personal communication from W. Lowder, describing measurements made by H. Beck and W. J. Condon in 1965.

Three other asbestos strip mines have been studied, the Ruberoid mine in Hyde Park, Vermont, the Johns Manville (Jeffrey) mine in Asbestos, Quebec, and the (King Beaver) mine in Thetford, Quebec. These sites, too, exhibited far less than "normal" exposure rates. A summary of the findings is given in Table 1. The comparatively higher reading at the Ruberoid mine may reflect the fact that data were obtained for only 1 day at this location, and this in rainy conditions. Furthermore, the practice at this mine is to rebuild the excavated areas with processed rock and soil, with the inherent possibility of including foreign materials. Compare the two readings for the Jeffrey mine. The second set was taken after an extended rainy period.

As well as these sites, underground salt mines apparently also exhibit rather low levels of radiation. For example, in a mine near Houston, an approximate level of 0.2 $\mu\text{r./h}$ has been determined. It is interesting that the contribution of potassium-40 was negligible, and that there was a substantial concentration of bismuth-214.

To scale the set of values in Table 1 properly, we have included some others. The first, an average of readings taken at an Atomic Energy Commission site in Polham, New York, is a representative sample of the magnitude encountered over soil. The next value listed, on the other hand, is rather high. It was obtained over a granite outcrop at Courtright Reservoir in the Sierras. (This site serves as a standard for the University of California LRL Health Physics group.) In addition there are, of course, "hotter" regions, the best example of which is the monazite sands area on the Brazilian East Coast, where levels up to 2,000 $\mu\text{r./h}$ are observed⁹.

The ultra-low levels listed in Table 1 are almost certainly associated with ultramafic rocks. This is entirely reasonable considering that the concentrations of the principal radioactive contaminants, uranium, thorium and potassium, vary, in the words of Wollenberg and Smith⁶, "with the acidity of igneous rocks, being practically nil in the ultramafic rocks". Davis and Hess¹⁰ showed that as the mafic nature of igneous rocks varied between felsic and ultramafic, the concentration of uranium changed from 3.0×10^{-6} to 0.03×10^{-6} g/g of rock. Included in their samples, coincidentally, were specimen rocks from Belvidere Mountain in Vermont, the site of the Ruberoid mine already mentioned. In addition to reporting that gravimetric determinations show "generally between 0.00 and 0.03% for the alkalis in ultramafic rocks", Hamilton and Mountjoy¹¹ also list the results of an extensive series of flame spectropho-

metric analyses on alpine ultramafic rocks, in which the median concentration of potassium oxide was 0.003 per cent. Dunite and serpentine were said to be virtually free of potassium¹². It is interesting that a constant ratio of potassium to uranium is said to occur¹³ in ultramafic rock. In addition, the fact that relatively large regions, either on the Earth's surface or close to it, show ultra-low radioactivity may have significance in connexion with (a) the hypothesis^{14,15} that the mantle immediately below the Mohorovičić discontinuity consists chiefly of ultra basic (peridotitic) rock, and (b) the fact that there are probably "quite severe restrictions . . . on the absolute concentrations of radioactive elements existing in the earth's upper mantle"¹⁶.

Apart from geochemical considerations, perhaps the most interesting aspect is the possible exploitation of such areas for research which requires extremely low backgrounds. Consider, for example, what information can be derived from Fig. 1, which shows the ionization level in Red Mountain mine recorded for 10 min. Full scale is approximately equivalent to 4.0 $\mu\text{r./h}$. The electrometer zero is shown at the end of the record. Zero drift was measured during this period and found to be negligible.

The large spikes represent bursts of ionization from alpha particles emitted by contaminants in the chamber walls. Some are shown in greater detail in Fig. 2, in a portion of record taken at a higher speed. For those times long after an alpha emission and before another, the mean signal level approaches a net deflexion of about 3/4 of a small division. The cosmic ray level at the mine elevation (3,040 ft.) is 4.3 $\mu\text{r./h}$, but is greatly attenuated by the 400 ft. of vertical thickness of rock above the ionization chamber. Assuming a specific gravity of 2.5, this corresponds to a depth of 3.1×10^5 g/cm², enough to reduce the cosmic ray contribution to the order of 0.01 $\mu\text{r./h}$, and the net magnitude to the previously stated 0.05 $\mu\text{r./h}$.

By direct counting of pulses for 30 min it was established that there were 0.036 ± 0.003 alphas/sec. This, divided by the interior surface area of the chamber, is equivalent to 1.2×10^{-5} alphas/cm²/sec. Sharpe¹⁷ has reported that aquadag coatings (which constituted the interior electrodes in our chamber) emit about 1.9×10^{-5} alphas/cm²/s. It is seen, therefore, that the residual contamination of the chamber itself is determined in a straightforward way. More elaborate schemes have been used in the past, notably the extrapolation techniques of Hess and Vancour¹⁸.

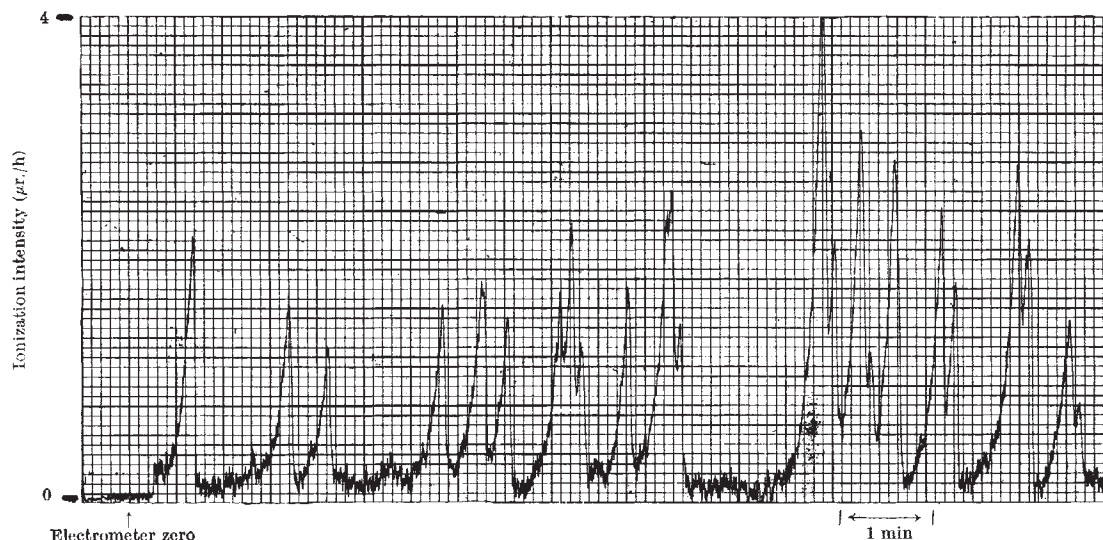


Fig. 1. Intensity of background ionization in the Red Mountain mine, showing the effect of wall alphas.

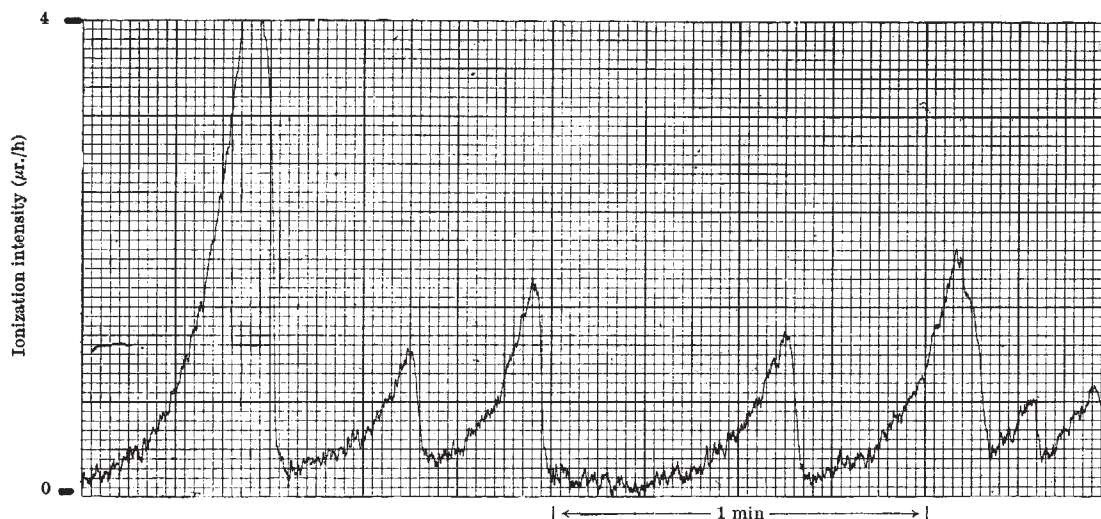


Fig. 2. The resolution of alpha activity in an ionization chamber.

As an example of the sort of experiment which could be carried out in the Red Mountain mine or, for that matter, in the mines in the Thetford region of Quebec, it has been shown¹⁹ that certain anomalous results in the cosmic ray depth-intensity relation below ground²⁰ can be explained as resulting from multiple Geiger counter coincidences caused by local gamma radiation. A substantial decrease in local background would enable such work to be carried out with much less shielding, which, as an added benefit, would yield more data about the low energy end of the underground cosmic ray spectrum. Cosmic ray surface measurements could probably be performed over such regions with little or no shielding, and with perhaps little in the way of anticoincidence protection. Other possibilities include the use of such areas for research in those problems in genetics and archaeological dating where very low background levels are required.

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- ¹ Neher, H. V., *Science*, **125**, 1088 (1957).
- ² Solon, L. R., Lowder, W. M., Zila, A. V., Levine, H. D., Blatz, H., and Eisenbud, M., *Science*, **127**, 1183 (1958).
- ³ Solon, L. R., Lowder, W. M., Shambon, A., and Blatz, H., *US Atomic Energy Comm. Health and Safety Lab. Report*, No. 73 (November 1959).
- ⁴ Hultqvist, B., *Kingl. Svenska Vetenskapsakademiens Handlingar*, **6**, No. 3 (1956).
- ⁵ Beck, H. L., Condon, W. J., and Lowder, W. M., *US Atomic Energy Comm. Health and Safety Lab. Report*, No. 145 (April, 1964).
- ⁶ Wollenberg, H. A., and Smith, A. R., *Earth Materials for Low Background Radiation Shielding* (Univ. Calif. Radiat. Lab., 9970, May 24, 1962).
- ⁷ Shamos, M. H., and Liboff, A. R., *J. Geophys. Res.*, **7**, 19 (1966).
- ⁸ Shamos, M. H., *Ann. Report, US Atomic Energy Comm. Div. Biol. and Med.*, **33** (1966).
- ⁹ Roser, F. X., and Cullen, T. L., in *The Natural Radiation Environment* (edit. by Adams, J. A. S., and Lowder, W. M.), 825 (University of Chicago Press, 1964).
- ¹⁰ Davis, G. L., and Hess, H. H., *Amer. J. Sci.*, **247**, 856 (1949).
- ¹¹ Hamilton, W., and Mountjoy, W., *Geochim. Cosmochim. Acta*, **29**, 661 (1965).
- ¹² Ahrens, L. H., in *Nuclear Geology* (edit. by Paul, H.), 131 (John Wiley, New York, 1954).
- ¹³ Wasserburg, G. J., MacDonald, G. J. F., Hoyle, F., and Fowler, W. A., *Science*, **144**, 465 (1964).
- ¹⁴ Ringwood, A. E., *J. Geophys. Res.*, **67**, 857 (1962).
- ¹⁵ Ringwood, A. E., *J. Geophys. Res.*, **67**, 4473 (1962).
- ¹⁶ Lovering, J. F., and Morgan, J. W., *Nature*, **197**, 138 (1963).
- ¹⁷ Sharpe, J., *Nuclear Radiation Detectors*, 98 (Methuen, London, 1955).
- ¹⁸ Hess, V. F., and Vancour, R. P., *Phys. Rev.*, **76**, 8, 1205 (1949).
- ¹⁹ Barton, J. C., and Michaelis, E. G., *Proc. Phys. Soc.*, **77**, 377 (1960).
- ²⁰ Barnothy, J., and Forro, M., *Phys. Rev.*, **74**, 1300 (1948).

PHYSICS

Stimulated Emission and Laser Action from the Organic Ligand of Gadolinium Chelates

WE wish to report evidence for stimulated emission and laser characteristics from liquid solutions of gadolinium organic chelates at room temperature. To our knowledge this is the first time that electronic transitions in organic chromophores have performed laser action under direct flash in liquid solution. The stimulated emission is reproducibly obtained at room temperature in conditions in which no fluorescence or phosphorescence is usually detected. With identical pumping energy, the coherent emission from the organic ligand in the Gd chelate is comparable with that obtained from solutions of europium¹⁻³ and terbium⁴ chelates in which the emitting species is the complexed lanthanide ion.

Three gadolinium chelates exhibited laser action at room temperature in solution: *tris*(theonyltrifluoroacetate)-Gd III (GdT₃), α, α' -dipyridyl-*tris*(theonyltrifluoroacetate)-Gd III (GdT₃Dipy), and 1,10-phenanthroline-*tris*(theonyltrifluoroacetate)-Gd III (GdT₃Phen). The procedures for their preparation have been described previously⁵⁻⁷. Solutions of 1×10^{-3} – 3×10^{-3} M in spectrograde acetonitrile (Columbia Organic Chemicals) were prepared and tested for laser action at room temperature. Removal of oxygen (deaeration) or prolonged storage did not significantly change the laser performance of the material.

The liquid laser cavities and the alignment techniques employed in this work have been described in detail before^{4,8}.

Fig. 1 shows the relaxation oscillations (spiking) observed above threshold from GdT₃Dipy in acetonitrile. The optimum concentration (lowest threshold) was found to be around 2.5×10^{-3} M for GdT₃Dipy, the most efficient of the three chelates reported here. The spectral distribution of the laser lines is displayed in Fig. 2. The broad band centred at 394 m μ is caused by the background light from the xenon flash lamp corresponding to a "window" in the filter system and is easily reproduced when the liquid cell is empty or filled with pure solvent. The very narrow laser lines are superimposed on the background emission. Beam collimation has also been observed above threshold on far-field images of the output obtained on Polaroid film. These results are reproducible.